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Properties of Polystyrene Bead Foam as an Encapsulant for Electronic Packages

By D. J. Fossey

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D. J. Fossey, Project Leader

Project Team:
D. C. Dyer
L. L. Holland
G. D. Swanson
K. A. Walburn
D. E. Walters
G. L. Woodburn

Technical Communications Bendix Kansas City Division

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Polystyrene bead foam (PSBF) was evaluated as an encapsulant for electronic packages. Various properties of PSBF pertinent to the expected environmental conditioning of a prototype electronic package were determined and evaluated for their effects on individual electronic components, within the package. It was determined that PSBF densities of 0.2 to 0.4 g/cm^3 provided adequate protection without damaging fragile electronic components. PSBF densities above 0.4 g/cm^3 provide adequate protection from the shock and vibration spectra evaluated, but could damage fragile electronic components during the encapsulation process and thermal cycling. Buildup of electrostatic voltage during encapsulation can be reduced to safe levels by grounding the case of the electronic package. Only the 0.6 g/cm^3 PSBF could be made impervious to moisture penetration.

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The Bendix Corporation
Kansas City Division
P. O. Box 1159
Kansas City, Missouri 64141

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CONTENTS

SUMMARY

Polystyrene bead foam (PSBF), a relatively new encapsulant for electronic packages, can be removed with common hydrocarbon solvents so that defective components can be easily replaced or repaired. PSBF densities ranging from 0.1 to 0.6 g/cm^3 were tested and evaluated for the following.

1. Mechanical properties,

2. Thermomechanical properties,

3. Shock and vibration protection,

4. Electrostatic voltage elimination, and

5. Moisture penetration.

The tensile and compressive properties of PSBF at densities of 0.1 to 0.6 g/cm^3 PSBF were determined at -54, 25, and 74°C. Test results showed that 0.1 g/cm^3 PSBF cannot be processed as an encapsulant for electronic packages because of poor bead fusion.

The thermomechanical stress and strains produced by the PSBF during fusion and thermal cycling were monitored for foam densities ranging from 0.2 to 0.6 g/cm^3. Densities of 0.4 g/cm^3 and below are safe encapsulants for electronic packages; higher densities could damage fragile electronic components in the system.

Shock and vibration tests showed that all densities of PSBF (0.2 to 0.6 g/cm^3) provide adequate protection to the electronic package over the shock and vibration spectra used.

The problem of electrostatic charge buildup was reduced when tests identified a safe way to fill electronic packages with polystyrene bead. Grounding the metal case of the electronic package and pouring the beads into the electronic package through a circular static bar produced near zero voltage.

Moisture penetration tests proved that only the 0.6 g/cm^3 PSBF could be molded to be impervious to moisture penetration at 1724 kPa for a 96-hour test.

DISCUSSION

SCOPE AND PURPOSE

Polystyrene bead foam (PSBF) is a relatively new encapsulant for electronic packages. Its main advantage is that it can be readily removed with common hydrocarbon solvents so that defective components can be easily replaced or repaired. PSBF properties were determined at densities ranging from 0.1 to 0.6 g/cm^3, and their environmental protection capabilities were evaluated. These properties included the following.

1. Mechanical properties,
2. Thermomechanical behavior,
3. Shock and vibration damping characteristics,
4. Electrostatic voltage buildup and elimination on sensitive electronic components, and
5. Moisture penetration resistance of PSBF.

PRIOR WORK

Previous work had been conducted to characterize 0.2 g/cm^3 PSBF as an encapsulant.[1]

ACTIVITY

Proven transducing techniques were used. The experiments evaluated particular components and conditions separately, using a package without electrical components as a test vehicle, and then performing final evaluations on a development equivalent package.

Mechanical Properties

Details and results of previous mechanical testing have been reported.[2] The tensile and compressive properties of PSBF were determined as a function of foam density and test temperature. The effects of the pentane content of the molded PSBF and fusion temperature on these properties were also determined. The PSBF densities investigated ranged from 0.1 to 0.6 g/cm^3 and were tested for their mechanical properties on molded-to-size test specimens at -54, 25, and 74°C.

Test results showed that 0.1 g/cm^3 PSBF cannot be processed as an encapsulant for electronic packages because of poor bead fusion. PSBF densities of 0.4 g/cm^3 and higher continue to expand at 74°C. Reducing the pentane or volatile content from 6 to 3 percent

in the pre-expanded polystyrene beads before molding and increasing the fusion temperature will allow the use of higher density PSBF at 74°C.

Thermomechanical Properties

Initial tests for thermomechanical properties of PSBF used the thumb tack physical model. Two thumb tack models were encapsulated in PSBF with densities of 0.3, 0.4, 0.5, and 0.6 g/cm^3. The 0.6 g/cm^3 PSBF density was evaluated for 3.6 and 6 percent initial pentane content. Load in the lead wire connecting the tack lead to the solder joint, movement in the solder joint, and crushing pressure on a transistor were measured for all conditions.[3]

All the PSBF densities evaluated were found mechanically safe for this thumb tack joint and for the specific transistor used as a pressure transducer. All densities were less severe encapsulants than 0.2 g/cm^3 polyurethane foams.

Loads and pressures do not change much for the PSBF density range from 0.4 to 0.6 g/cm^3. Foams of these densities are nearly equal encapsulants in terms of the thermomechanical load on solder joints and the pressure on electronic components. No true movement of the lead in the solder joint was measured.

The next set of tests involved strain gaging a dummy electronic package without electronic components to measure loadings and deflections caused by the PSBF during fusion and thermal cycling.[4] A variety of proven strain-gage transducers was used to measure loads and deflections. The quantities measured were the deflection of printed wiring boards (PWBs) normal to their plane, localized strain in the plane of PWBs, lateral force parallel to the surface of a PWB, lateral deflection parallel to the surface of a PWB, and the thermomechanical pressure on a strain-gaged transistor. These quantities were judged to have the highest potential for damaging electronic components in packages encapsulated in PSBF.

Low-density PSBF is flexible enough to eliminate the need for conformal coatings to protect electronic components required by more rigid encapsulants. Nearly equally low loadings and deflections were measured for 0.2 and 0.3 g/cm^3 PSBF; values for 0.4 g/cm^3 were intermediate; and densities of 0.5 and 0.6 g/cm^3 produced nearly equally high loadings and deflections.

Robust electronic components such as inductors should be safe in all densities, but care must be used when encapsulating fragile electronic components like ceramic microcircuits in the highest two densities, where fairly large crushing pressures can develop.

If PWBs are not fixed rigidly in place by support posts or fixtures, significant movement can occur during the fusion cycle. Therefore,

all electronic components must be adequately protected from electrical shorting or from change in critical circuit parameters which may result from such movement. After fusion, the PWBs usually do not move.

Previous encapsulant materials have bonded well to most materials. However, only negligible bonding is obtained between PSBF and other materials. Therefore, electronic components may encounter different modes and magnitudes of loads and deflections.

To investigate these effects, the strain caused by the pressure loading of several electronic microcircuits was measured. Representatives of those microcircuits were then strain-gaged and monitored during encapsulation and thermal cycling successively in 0.2, 0.4, and 0.6 g/cm^3 PSBF. The result: low density foams are safe for all components, but fragile components may be damaged by 0.6 g/cm^3 PSBF.[5]

Strain versus temperature data were nonlinear, and the response to the first cooling was different from each subsequent cooling. Thus, reliable stress calculations cannot be made without a detailed understanding of the reasons for such behavior. Also, identical components at different locations in the package can experience quite different loadings.

To predict thermally-generated stresses on electronic components, the thumb tack physical model of an electronic component used in earlier experimental studies was used in a finite element method (FEM) stress analysis. The solder joint stress distribution was calculated in one model, and lead wire stresses from the full thumb tack physical model were compared with experimental values.

The maximum Von Mises stress and the maximum magnitude of the R-Z shear stress in the solder joint were near the origin of failure in thermal fatigue tests. However, calculated lead wire stresses did not agree with experimental data.

A reanalysis of the experimental data showed a nonlinear load versus temperature plot. The first break in a segmented straight line fit correlated well with the PSBF glass transition temperature (Tg). The reason for the other breaks is not known. Those breaks imply that any linear elastic stress analysis of PSBF encapsulation stresses must be done very carefully and must be applied in steps over the temperature range of each straight line segment.

High stresses above the tensile limit were calculated in the PSBF around the tack. These stresses could crack the PSBF and cause a load relaxation. The thumb tack physical model data, therefore, must be evaluated carefully for each specific candidate encapsulant and when comparing stresses caused by several encapsulants.

Additional work needs to be done before limits can be defined for applying the thumb tack physical model to encapsulant evaluation. Limits also need to be defined for applying linear elastic stress analysis to components or assemblies encapsulated in PSBF and for simulating nonbonding of PSBF to other materials.

Shock and Vibration

To determine the shock and vibration damping characteristics of PSBF, three miniature triaxial accelerometers were mounted in the dummy unit and in the production equivalent unit. The response of the accelerometers to mechanical shock and vibration was monitored.

The electronic package must be potted into the shock and vibration test fixture in order to eliminate spurious resonances caused by rattling. When the unit was tightly secured in the test fixture, the shock and vibration results showed that the energy output was essentially the same as the energy input for all densities of PSBF tested. All densities of PSBF provided adequate protection for the shock and vibration conditions used.

Electrostatic Voltage Elimination

Electrostatic voltages can damage sensitive electronic components when pre-expanded polystyrene beads are poured into an electronic package. A series of electrostatic voltage tests identified a safe method of filling electronic packages with polystyrene beads. Near zero voltage was developed when the metal case of the electronic package was grounded and the beads were poured into the electronic package through a circular static bar. However, hand-held anti-static guns can generate 1,000 V and must be used with care.

Moisture Penetration

It was of some interest to determine the high-pressure moisture penetration resistance of PSBF. Because no standard techniques or equipment were known, a test fixture was built and a procedure was developed to obtain this information.[6]

One slab for each allowable fusion time and temperature for each PSBF density from 0.2 to 0.6 g/cm^3 was evaluated. Each condition that withstood the required 1724 kPa water pressure for 24 hours was submitted to extended testing for at least 96 hours. These replicates also proved to be impervious to moisture penetration.

The higher densities of PSBF were less porous. Higher fusion temperatures and longer fusion times for a given density also increased resistance to moisture penetration. Only the 0.6 g/cm^3

PSBF was impervious for only 3 of the 8 fusion conditions evaluated. The adequate conditions were 115 and 125°C for 60 minutes and 125°C for 40 minutes.

ACCOMPLISHMENTS

The tensile and compressive properties of PSBF were determined as a function of density (0.1 to 0.6 g/cm^3) at three test temperatures (-54, 25, and 74°C). Results showed the following.

1. PSBF can be successfully processed as an encapsulant with densities ranging from 0.2 to 0.6 g/cm^3.

2. PSBF with densities up to 0.4 g/cm^3 is a safe encapsulant for most electronic packages. Thermomechanical stresses do not damage any electronic circuits. Densities of PSBF above 0.4 g/cm^3 may produce damaging thermomechanical stresses on some fragile and electronic components.

3. All PSBF densities from 0.2 to 0.6 g/cm^3 will provide adequate protection to electronic packages subjected to the shock and vibration spectra evaluated in this study.

4. A procedure has been identified which will protect sensitive electronic components from electrostatic voltages generated during filling and assembly with PSBF. Electrostatic voltage buildup can be reduced to safe levels by grounding the case of the electronic unit during the filling operation.

5. A test fixture and related techniques have been developed and used to measure resistance to moisture penetration of flat PSBF slabs ranging in density from 0.2 to 0.6 g/cm^3 and fabricated at various fusion times and temperatures. Only three fusion conditions were identified as impervious to moisture penetration at 1724 kPa for the 96-hour test: all were 0.6 g/cm^3 density.

FUTURE WORK

No future work for this project is planned. Additional work may be required for new applications of PSBF as an encapsulant. The proper fusion cycle required for each new application will have to be determined to ensure complete fusion of the polystyrene beads through the electronic unit.

REFERENCES

[1]D. J. Fossey, Evaluation of Polystyrene Bead Foam as an Encapsulant for MC2823 (Final Report). Bendix Kansas City: BDX-613-2021, June 1978 (Available from NTIS).

[2]D. J. Fossey, Mechanical Properties of Polystyrene Bead Encapsulation Foam (Topical Report). Bendix Kansas City: BDX-613-2412, May 1980 (Available from NTIS).

[3]D. J. Fossey and G. D. Swanson, Thumb Tack Physical Model Evaluation of Polystyrene Bead Foam as an Encapsulant for Electronic Packages (Topical Report). Bendix Kansas City: BDX-613-2416, March 1980 (Available from NTIS).

[4]G. D. Swanson, Multi-Transducer Dummy Unit Evaluation of Polystyrene Bead Foam as an Encapsulant for Electronic Packages (Topical Report). Bendix Kansas City: BDX-613-2488, October 1980 (Available from NTIS).

[5]G. D. Swanson, Finite Element Method Study of Stresses on Simulated Electronic Components Encapsulated in Polystyrene Bead Foam (Topical Report). Bendix Kansas City: BDX-613-2551, March 1981 (Available from NTIS).

[6]G. D. Swanson, Moisture Penetration Evaluation of Polystyrene Bead Foam as an Encapsulant for Electronic Packages (Topical Report). Bendix Kansas City: BDX-613-2394, July 1980 (Available from NTIS).

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